AMSAR/SA/N - 11

DECISION RISK ANALYSIS
OF
SITE SELECTION FOR PRODUCTION
OF THE 105MM PROJECTILE, XM710

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JANUARY 1976

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US ARMY ARMAMENT COMMAND
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This report describes a risk analysis performed on the selection of a lowest cost producer for the initial production of XM710 ICM 105mm ammunition. The report assesses the risk associated with selection of a lowest cost producer when indirect expense is either included or excluded from the cost comparison. On the basis of this analysis, it is concluded that there is a risk involved in not including indirect expense as part of the cost comparison. It is also concluded that the addition of transportation costs to the economic analysis

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would not significantly change the risk associated with the selection of a lowest cost producer.

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INTRODUCTION

In July of 1974, at the request of the AMC Project Manager for Selected Ammunition, Headquarters, ARMCOM, initiated site selection procedures to determine a plant location for load, assemble and pack (LAP) of the XM710 Improved Conventional Ammunition (ICM) 105mm projectile. Proposals were solicited and received from five Army Ammunition Plants showing costs and economic analyses for proposed automated lines. The ARMCOM Comptroller's review of the plant submissions concluded that the overhead costs estimated by the various plants were not developed in a consistent manner. Because of fluctuating workload conditions at the plants, it was felt that overhead costs were difficult to obtain for current workloading and impossible to predict for a ten year period. Because of these uncertainties surrounding estimates of overhead costs, the overhead costs were deleted from the economic analysis used to select the lowest cost producer. Based upon the cost comparison which excluded overhead costs, Iowa Army Ammunition Plant (AAP) was selected as the lowest cost producer for LAP of 45,000 XM710 rounds per month. When overhead costs were included in the economic analysis in accordance with estimates submitted by the candidate plants, the economic ranking of the alternatives changed with Longhorn AAP becoming the lowest cost producer. Table 1 shows the results of the ARMCOM site selection study economic analysis.

Costs of transportation, while shown separately in the site selection study, were not included in the economic analysis used to select the lowest cost producer. The site selection study concluded that transportation costs were in favor of Iowa AAP in all cases; however, the study was predicated upon a 65 percent to 35 percent ratio of west coast and east coast shipments.

TABLE 1. SITE SELECTION STUDY UNIFORM ANNUAL COSTS WITH AND WITHOUT OVERHEAD[a]

AAP	WITHOUT INDIRECT EXPENSE	WITH INDIRECT EXPENSE
Iowa	1,142,044 (1)	3,822,772 (3)
Longhorn	1,159,267 (2)	3,043,761 (1)
Louisiana	1,323,603 (3)	3,202,346 (2)
Milan	2,601,003 (4)	6,395,441 (4)
Kansas	3,836,782 (5)	9,145,408 (5)

[a]Ranking shown in parentheses

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On 15 May 1975, the Director of Procurement and Production tasked the Systems Analysis Directorate to conduct a risk analysis which would quantify the risk associated with excluding overhead from the economic analysis when selecting a lowest cost plant. Preliminary results were presented to the Director of Procurement and Production on 16 June and final results were presented to the CG, ARMCOM on 30 June 1975. While the results of this analysis indicate that Iowa AAP still represents the lowest risk alternative, the certainty of that selection is materially affected by the inclusion of incremental indirect expenses.

DEFINITION OF PROBLEM

Examination of the costs displayed in Table 1 shows that, either with or without overhead, the costs of the three lowest cost plants are very close. In order to show the true risk of excluding overhead from the cost comparison, it was necessary to make two separate risk assessments—the first based upon only investment and direct labor costs and a second based upon those same costs with overhead added. The comparison of the two separate risk assessments gives an indication of the impact of overhead on the overall risk.

In addition to the risk analysis for overhead costs, an analysis of transportation costs was performed which examined the sensitivity of transportation costs to the shipment mix to east coast and west coast ports. The analysis of transportation costs was then extended by adding transportation costs to the economic analysis so that the sensitivity of the risk to transportation costs could be examined.

ALTERNATIVES

The analysis is limited to Longhorn, Louisiana, and Iowa AAPs. The costs of the other two plants are felt to be so much higher that the treatment of indirect expense would not change their economic rankings. Four different combinations of workload levels at the three alternative sites were examined. These alternatives were:

1. All plants operating at low workload levels with XM710 production as an added workload.

2. Iowa AAP operating at a low workload level with XM710 production as an added workload and as the only production at Longhorn AAP or Louisiana AAP.

3. Iowa and Louisiana operating at a low workload level with XM710 production as an added workload and as the only production at Longhorn AAP.

4. Iowa and Longhorn AAPs operating at a low workload level with XM710 as an added workload and as the only production at Louisiana AAP.

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DISCUSSION

This risk analysis is based upon an independent assessment of over-
head and General And Administrative (G&A) expense, also referred to as
indirect expense. It does not employ the overhead and G&A rates proposed
by the plants in their submissions, but predicts the annual incremental
indirect expense for each plant that would be associated with production
of the XM710 as an incremental workload. The data used to develop the
independent assessment are from the information contained in the Con-
tractors Monthly Plant Cost Statement, commonly referred to as the 3007A
report. These reports provide monthly direct labor, overhead, and G&A
information for each of the plants from mid-1969 through April of 1975.
The information from these reports was grouped into annual totals and
adjusted to 1975 dollars using the average annual direct labor rate of
each plant as the basis for the adjustment. The partial year data for
1969 and 1975 was extrapolated to show a full year's data. Table 2 shows
the 3007A report information used for each of the three plants.

The least squares method was then used to establish a relationship
between direct labor staffing and incremental indirect expense. For
each of the plants two analyses were made, one for the average plant
workload depicted by years 1969 through 1975 and another for the rela-
tively low average workload depicted by years 1971 through 1975. Figures
1, 2, and 3 show graphic portrayals of the direct labor to indirect
expense relationship for each plant. It should be noted that the slope
values show a tendency to level out as the average annual direct labor
staff decreases and also, that the changes in the slope for the period
1969-1975 vs. 1971-1975 for both Longhorn and Louisiana are quite large.

From this point it was necessary to establish a range estimate which
adequately described the uncertainty surrounding the indirect expense
estimate. A uniform distribution consisting of a low and high estimate
was felt to be most suitable. The low estimate for each plant was
established at zero incremental indirect expense. In selecting this as
the low value it assumes that a plant may be on the flat part of what
is really a step function. The analysis of Longhorn AAP for years 1971-
1975 indicated that additional direct labor could be added with no
increase in incremental indirect expense. The high estimate for the
uniform distribution was established as the product of the slope value
of the 1969-1975 analysis and the estimated direct labor staffing for
XM710 production at each plant.

In order to be as compatible as possible with the definition of
indirect expense in the 3007A reports, it was necessary to make adjust-
ments to the direct labor staffing employed in the site selection study.
The risk analysis direct labor staffing for Louisiana AAP was 75 personnel,
a figure which does not include production foremen, inspection foremen,
or millwrights. This estimate for Louisiana AAP was taken from the

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TABLE 2.   SUMMARY OF DATA IN CONSTANT 1975 DOLLARS/
CONTRACTORS MONTHLY PLANT COST STATEMENT

	Louisiana AAP		Longhorn AAP		Iowa AAP	
	Personnel Direct Labor	Overhead Plus G&A	Personnel Direct Labor	Overhead Plus G&A	Personnel Direct Labor	Overhead Plus G&A
1969	3013	$52,767,000	1393	$23,976,000	2589	$33,698,000
1970	2129	45,347,000	811	16,263,000	1552	22,224,000
1971	952	17,626,000	465	10,727,000	893	17,853,000
1972	337	12,251,000	468	10,452,000	751	17,808,000
1973	290	10,907,000	340	10,834,000	686	16,305,000
1974	229	9,258,000	331	10,421,000	544	14,086,000
1975	315	9,480,000	411	9,279,000	432	15,103,000

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LONGHORN AAP

1969-1975 Data

$$Y = \$4{,}886{,}000 + \$13{,}591X$$

ANNUAL OVERHEAD

PLUS G&A EXPENSE

IN MILLIONS

69

70

71-75

DIRECT LABOR PERSONNEL
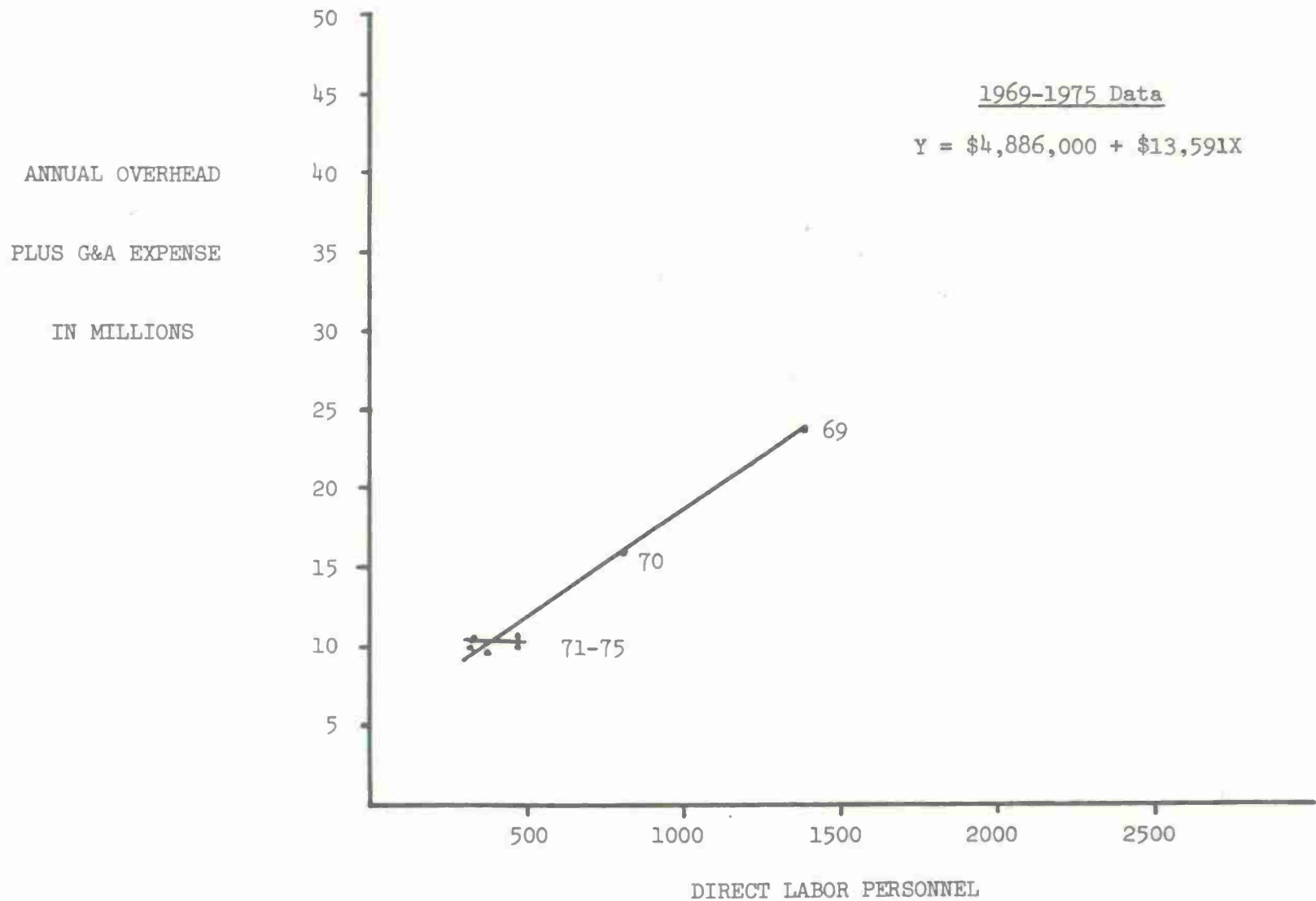
Figure 1. Direct Labor Hours vs. Indirect Expense - Longhorn AAP
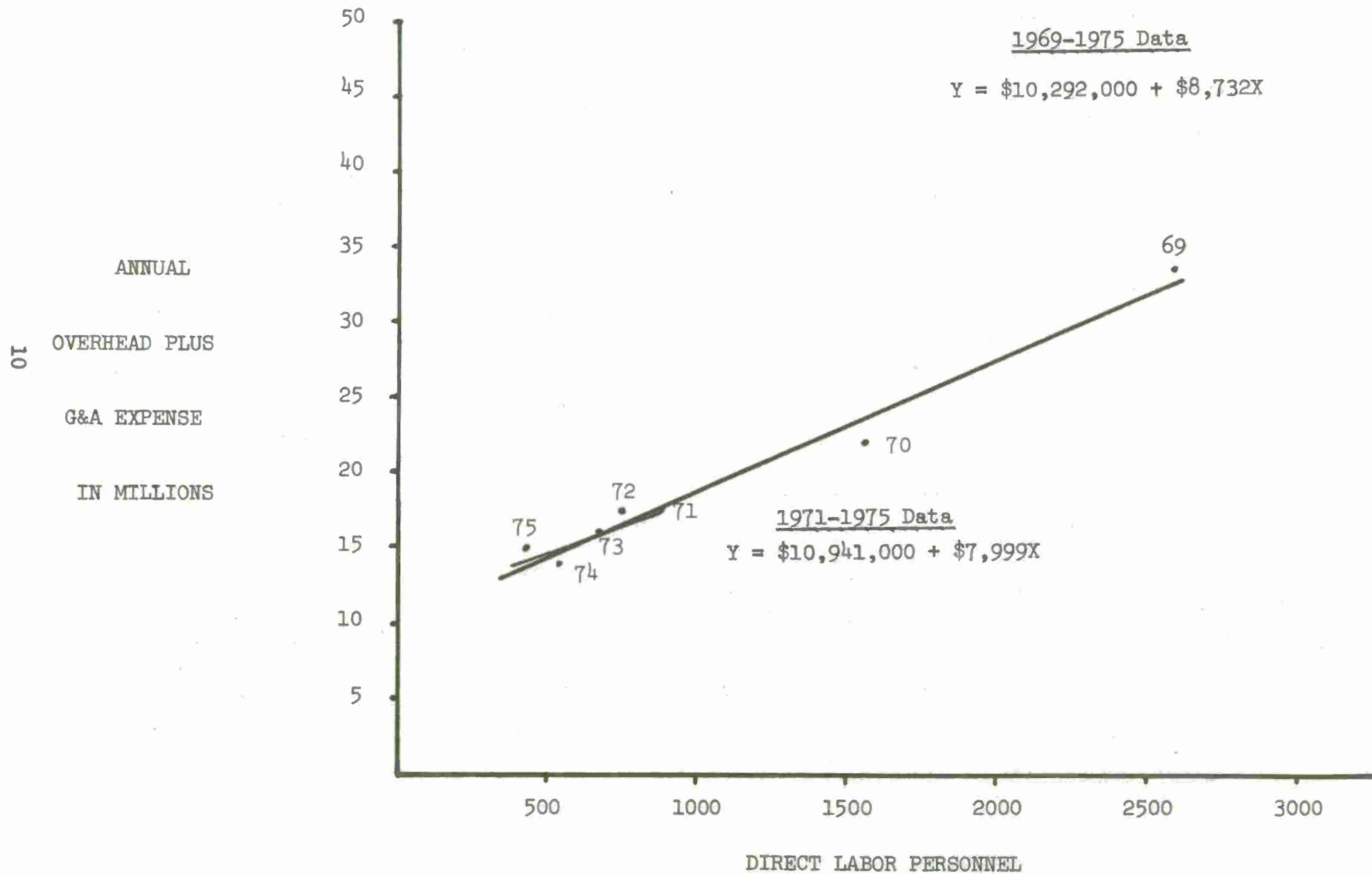
Figure 2. Direct Labor Hours vs. Indirect Expense – Iowa AAP

LOUISIANA AAP

ANNUAL

OVERHEAD PLUS

G&A EXPENSE

IN MILLIONS

11

50

45

40

35

30

25

20

15

10

5

• 69

• 70

1969-1975 Data

Y = $5,364,000 + $16,530X

71   1971-1975 Data

Y = $7,224,000 + $11,024X

72-75

500   1000   1500   2000   2500   3000
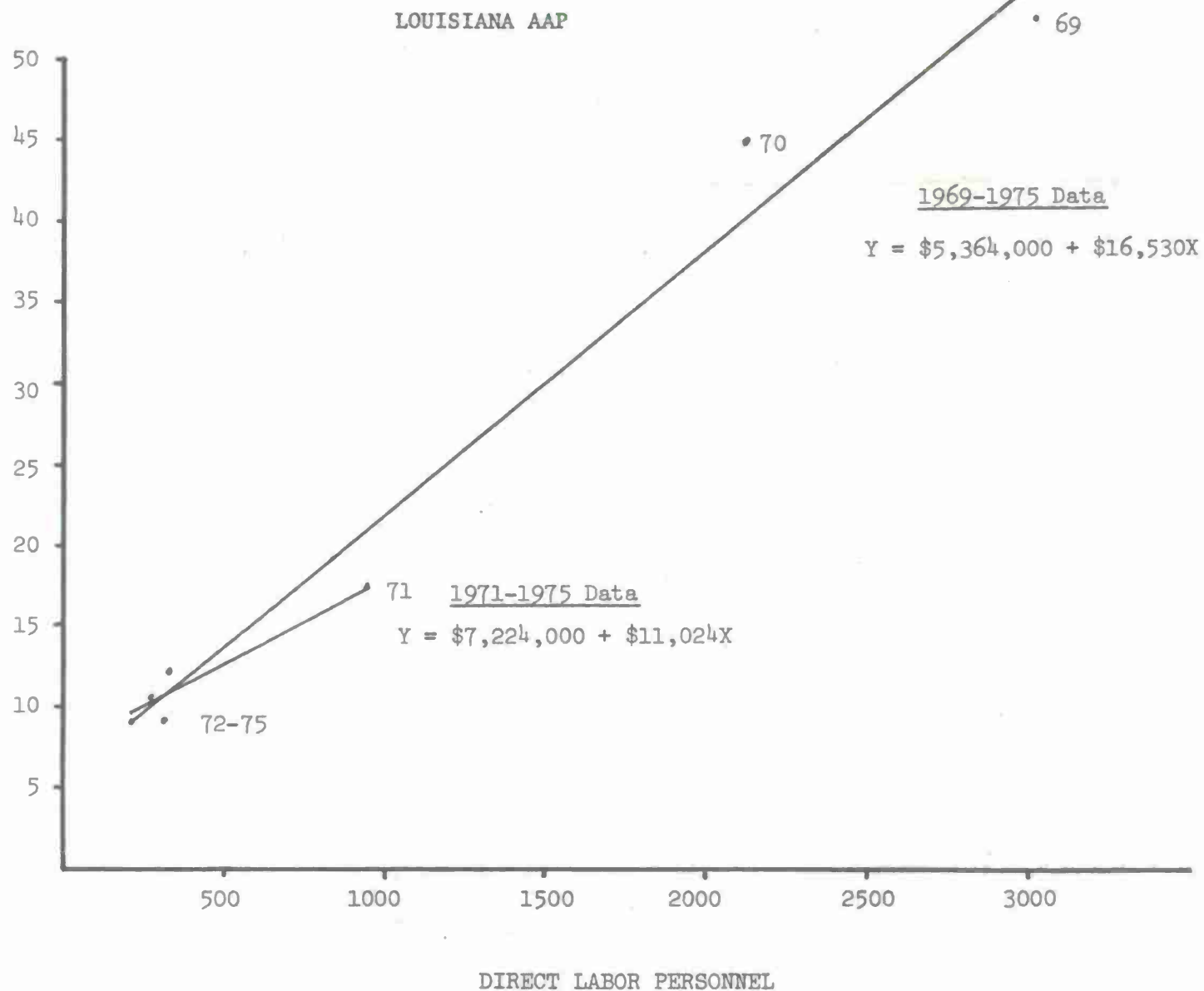
DIRECT LABOR PERSONNEL

Figure 3.   Direct Labor Hours vs. Indirect Expense - Louisiana AAP

revised proposal of Louisiana AAP. Production foremen, inspection foremen, and millwrights were likewise deleted from the proposed direct labor staffing at Iowa AAP for a direct labor estimate of 78 personnel. The estimated direct labor staffing for Longhorn AAP was 79 personnel taken from the proposal submitted by Longhorn AAP. These estimates of direct labor staffing were then costed at the same average direct labor rate that was employed in the site selection study.

In the alternatives for which the XM710 was assumed to be the sole production at one of the candidate plants, a triangular distribution consisting of a most likely, a low, and a high estimate was used to describe the range of indirect expense uncertainty. The high estimate was taken as the intercept value of the best fit line for the 1969-1975 analysis. The most likely estimate was then computed as the difference between the annual cost of standby staffing and the intercept value of the 1969-1975 workload analysis for each plant. This methodology assigned an indirect expense value to XM710 production equal to that of coming out of standby status and producing only one product. The low estimate was developed in the same manner as the most likely estimate except that values of standby cost at higher staffing levels were employed.

The distribution used to describe the uncertainty surrounding the investment and direct labor estimates was a normal distribution. Data available from other studies was used to establish a reasonable expected variation for investment estimates and direct labor estimates.

The procedures described above were used to prepare the cost distributions which were then used as input into the Venture Evaluation Risk Technique (VERT) program. Table 3 shows the various estimates that were developed for each plant and for each alternative.

The cost inputs shown in Table 3 were then processed through the computerized Venture Evaluation Risk Technique in a series of computer runs. The first run used only the direct labor and investment cost inputs for each plant. Succeeding runs added indirect expense cost input for each plant in accordance with the four plant workloading combinations which were studied.

RESULTS

Table 4 shows the results of the five VERT runs. The column labeled "without indirect expense" shows the frequency with which a plant was selected from the direct labor and investment cost only comparison. The column labeled "with indirect expense" shows the frequency when indirect expense is added.

When indirect expense is omitted from the cost comparison, Iowa AAP is the least risk choice. The predicted risk of being incorrect when selecting Iowa AAP is 100 percent minus 63 percent or 37 percent. Thus,

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TABLE 3. SUMMARY OF COST INPUTS

IOWA AAP

	Low	Most Likely	High
Direct Labor	578,882	683,447	788,012
Investment	171,001	221,957	272,813
Indirect Expense	000,000		681,096

LONGHORN AAP

	Low	Most Likely	High
Direct Labor	506,050	597,460	688,870
Investment	250,960	325,006	399,052
Indirect Expense	000,000		1,073,689
Ind Exp (XM710 Only Production)	3,042,000	3,982,440	4,886,000

LOUISIANA AAP

	Low	Most Likely	High
Direct Labor	470,294	555,245	640,196
Investment	341,035	442,612	544,189
Indirect Expense	000,000		1,239,750
Ind Exp (XM710 Only Production)	2,121,754	3,321,294	5,363,754

even the least risk choice is greater than a one out of three chance of being incorrect. When indirect expense is omitted from the cost comparison, the risk associated with selecting Longhorn AAP is 65 percent and the risk associated with selecting Louisiana AAP is 98 percent.

When indirect expense is included in the cost comparison, the risk associated with selection of a given plant varies according to the alternative under study. In all cases, however, Iowa AAP is the least risk choice. With indirect expense in the cost comparison for Alternative One, where all plants are producing at a low workload level, the risk associated with selecting Iowa AAP is 44 percent. When indirect expense was omitted the corresponding risk was predicted to be 37 percent. Thus, the risk of an incorrect decision when selecting Iowa AAP is greater than the investment and direct labor comparison would indicate.

With alternative two, where Longhorn AAP and Louisiana AAP are assumed to have the XM710 as their sole production, the risk of omitting indirect expense is clearly seen. The investment and direct labor comparison would favor Iowa AAP with a risk of 37 percent, while the addition of indirect expense shows that Iowa is in reality a predicted zero risk choice. With indirect expense included in the comparison for a plant which has the XM710 as its sole workload, the plant drops from contention as a lowest cost alternative.

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TABLE 4. SUMMARY OF RISK PREDICTIONS --
PROBABILITY OF BEING LOWEST COST PLANT

	ALTERNATIVE	PLANT	PROBABILITY WITH INDIRECT EXPENSE	PROBABILITY WITHOUT INDIRECT EXPENSE
1.	All plants open at Low Workload Level	Iowa Longhorn Louisiana	56% 28% 16%	63% 35% 2%
2.	XM710 the only Production at Longhorn or Louisiana	Iowa Longhorn Louisiana	100% - -	63% 35% 2%
3.	XM710 the only Production at Longhorn	Iowa Longhorn Louisiana	77% - 23%	63% 35% 2%
4.	XM710 the only Production at Louisiana	Iowa Longhorn Louisiana	67% 33% -	63% 35% 2%

CONCLUSIONS

On the basis of this analysis, it is concluded that there is a risk involved in not including overhead as a part of the cost comparison. This risk changes considerably with the assumed workload status of the given plants. In summary, Iowa AAP remains the least risk choice; however, it is a higher risk selection than the investment and direct labor cost comparison would indicate, assuming all plants will remain open at low workload. The risk increases from 37 to 44 percent with the omission of indirect expense.

ADDITIONAL ANALYSIS--TRANSPORTATION COSTS

The site selection study concluded that Iowa has the lowest transportation costs of any of the three leading candidates. This conclusion is based upon a transportation mix of east coast and west coast ports which provides for shipment of 35 percent of all rounds to Sunny Point, North Carolina and 65 percent to Concord, California. Prior experience of this directorate has indicated that a transportation mix showing a heavier mix shipped to the east coast would be more appropriate. To illustrate the impact upon transportation costs of a heavier mix shipped to the east coast, two supplementary analyses were conducted: (1) the assumption of a 60 percent to 40 percent mix of east coast to west coast shipments and (2) the assumption of a 100 percent east coast mix. Table 5 shows the results of the analysis.

It should be noted that the transportation cost summary which shows 100 percent shipment to the east coast no longer favors Iowa as the lowest cost producer facility. Thus, it is concluded that the costs of transportation are sensitive to the shipping mix of east and west coast ports.

As a check on the sensitivity of transportation costs on the risk of selection of the lowest cost plant, the transportation costs were added to the investment, direct labor and indirect expense and processed through VERT. The cost distribution used to portray the variation in transportation costs was a triangular distribution with low and high values at minus and plus 10 percent of the most likely. The resulting predicted frequencies of lowest cost alternative are shown below:

Iowa AAP   57%

Longhorn AAP   23%

Louisiana AAP   20%

Thus, it is concluded that the addition of transportation costs to the economic analysis would not significantly change the risk associated with the lowest cost plant selection.

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TABLE 5. ANALYSIS OF XM710 SITE SELECTION
TRANSPORTATION COSTS

	Iowa AAP		Longhorn AAP		Louisiana AAP	
	100% East Coast	60% East Coast	100% East Coast	60% East Coast	100% East Coast	60% East Coast
Shipment of metal parts from Chamberlain per month	8,353	8,353	20,309	20,309	16,214	16,214
Shipment of A-5 from Newport per month	10,759	10,759	11,534	11,534	9,180	9,180
Shipment of 45,000 XM710 East or West Coast port per month	76,518	82,919	64,507	74,270	63,207	78,658
Monthly Total Transportation Cost	95,630	102,031	96,351	106,113	88,601	104,052
Yearly Total Transportation Cost	1,147,560	1,224,372	1,156,212	1,273,356	1,063,212	1,248,624

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